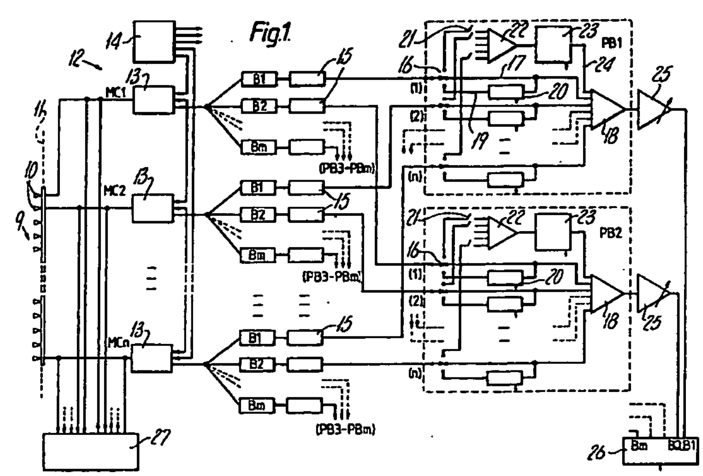
(12) UK Patent Application (19) GB (11) 2 097 121 A

(21) Application No 8112136
(22) Date of filing 21 Apr 1981
(43) Application published 27 Oct 1982
(51) INT CL³ G01S 3/82
(52) Domestic classification G1G 3A 3R 5A3B 5D RC
(56) Documents cited None
(58) Field of search G1G
(71) Applicants
Ferranti Limited,
Bridge House,
Park Road,
Gatley,
Cheadle,
Cheshire SK8 4HZ
(72) Inventor
Michael John Greenwood
(74) Agents
Ferranti Limited,
(A. R. Cooper),
Bridge House,
Park Road,
Gately,
Cheadle,
Cheshire SK8 4HZ

(54) Directional acoustic receiving array

(57) An acoustic telescope (Fig. 1) comprises an array 9 of omnidirectional microphone transducers 10 signals of which are delayed by different amounts in delay elements 13 by a microprocessor 14 which forms a directional reception beam for the array. The signals on each microphone channel are split into a number of bands by filters B1 . . . . Bm and corresponding band limited signals from all channels processed band-by-band in processing means PB1, PB2 etc. in which the signals are subject to amplitude shading (20) or pattern multiplication (23) to increase or decrease respectively the received beam width in relation to the desired beam width. At frequencies above that for which the desired beam width is natural the beam is broadened and for those below narrowed to equalise the beam widths for all the band limited signals irrespective of frequency. The signals are mixed at 26 to provide a real-time audio output of sources only from within the region of the desired beam width. Microphone signals may be recorded for replay and a different beam pattern imposed on them. Multiple arrays may be combined to define a beam in more dimensions. The acoustic telescope may be employed in a reconnaissance system (Fig. 3, not shown) in which the transducer signals are transmitted to a ground station where beam forming, processing and listening are controlled and take place.



GB 2 097 121 A

2097121

1/4

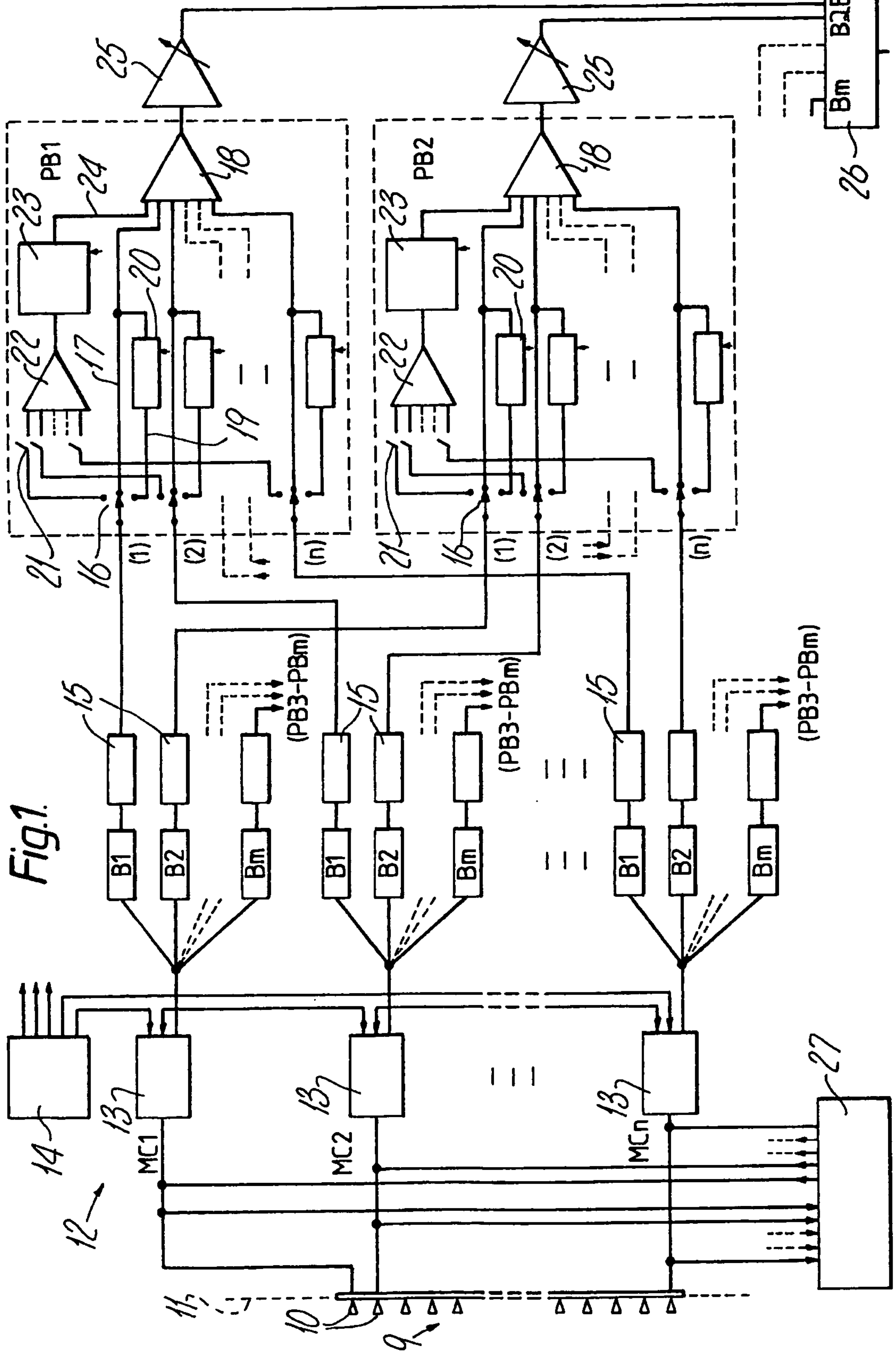


Fig.1.

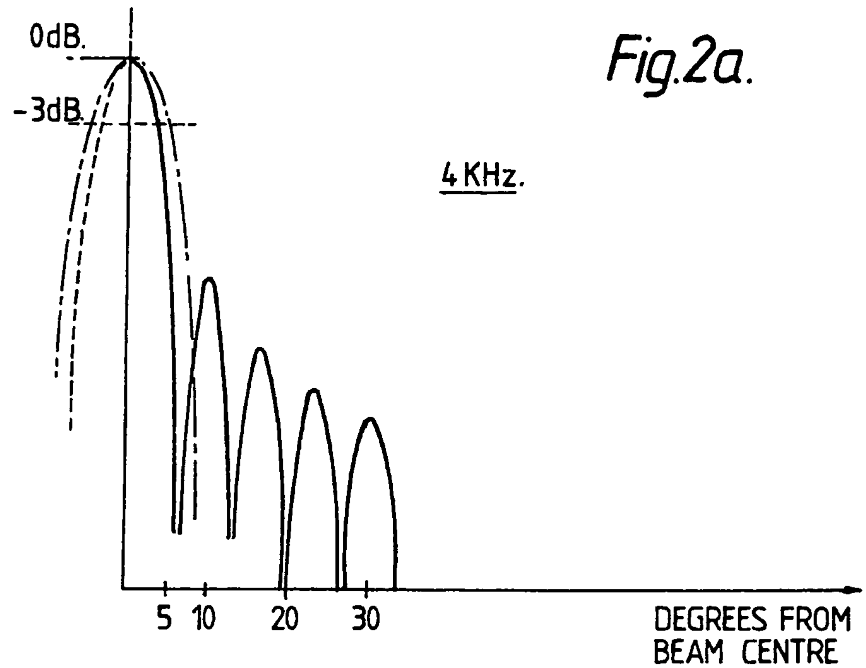

0dB.
-3dB
4KHz.
5
10
20
30
DEGREES FROM
BEAM CENTRE

Fig.2a.

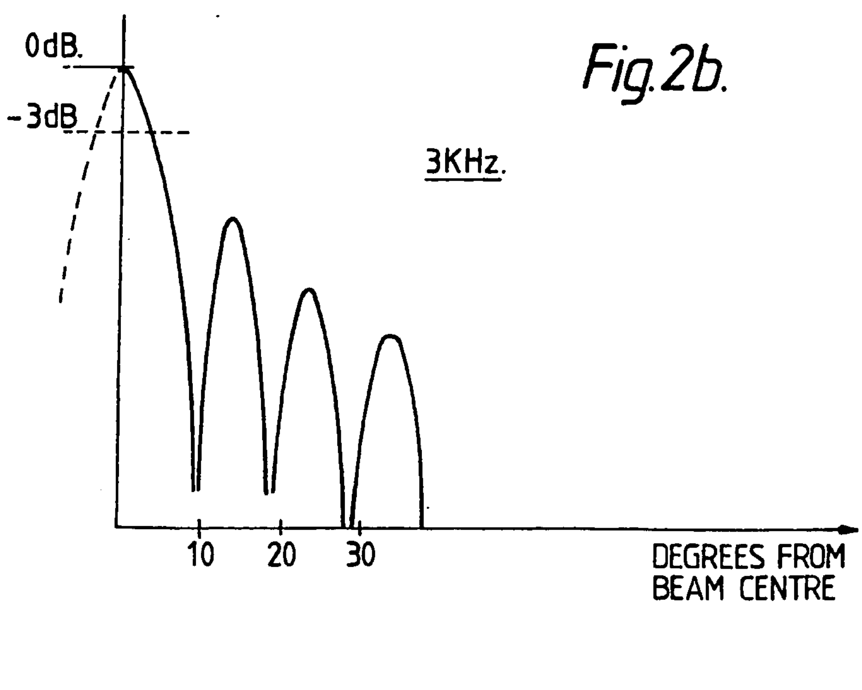

0dB.
-3dB
3KHz.
10
20
30
DEGREES FROM
BEAM CENTRE

Fig.2b.

Fig.2c.

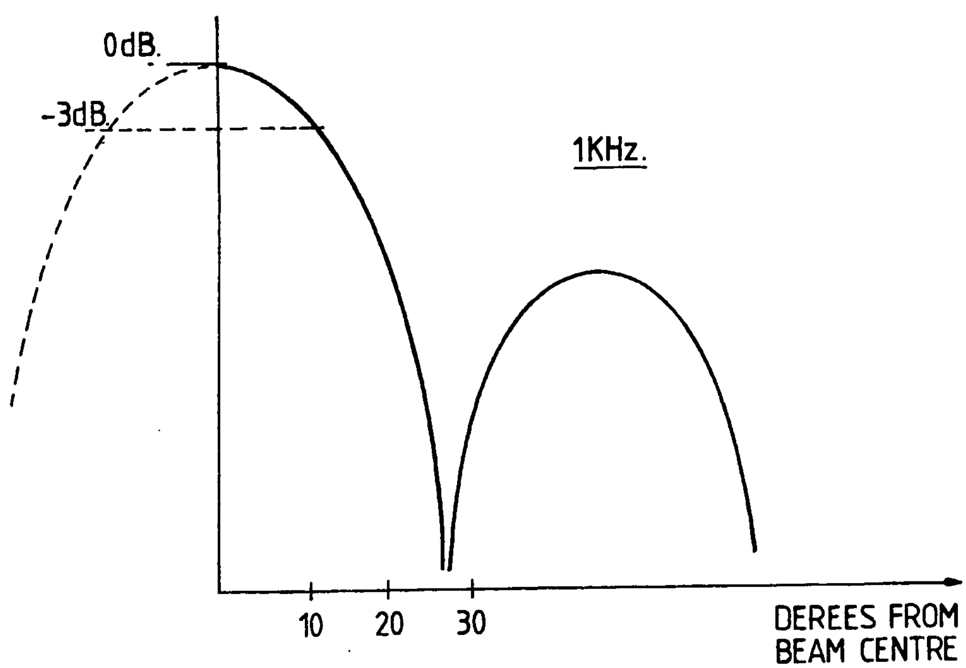
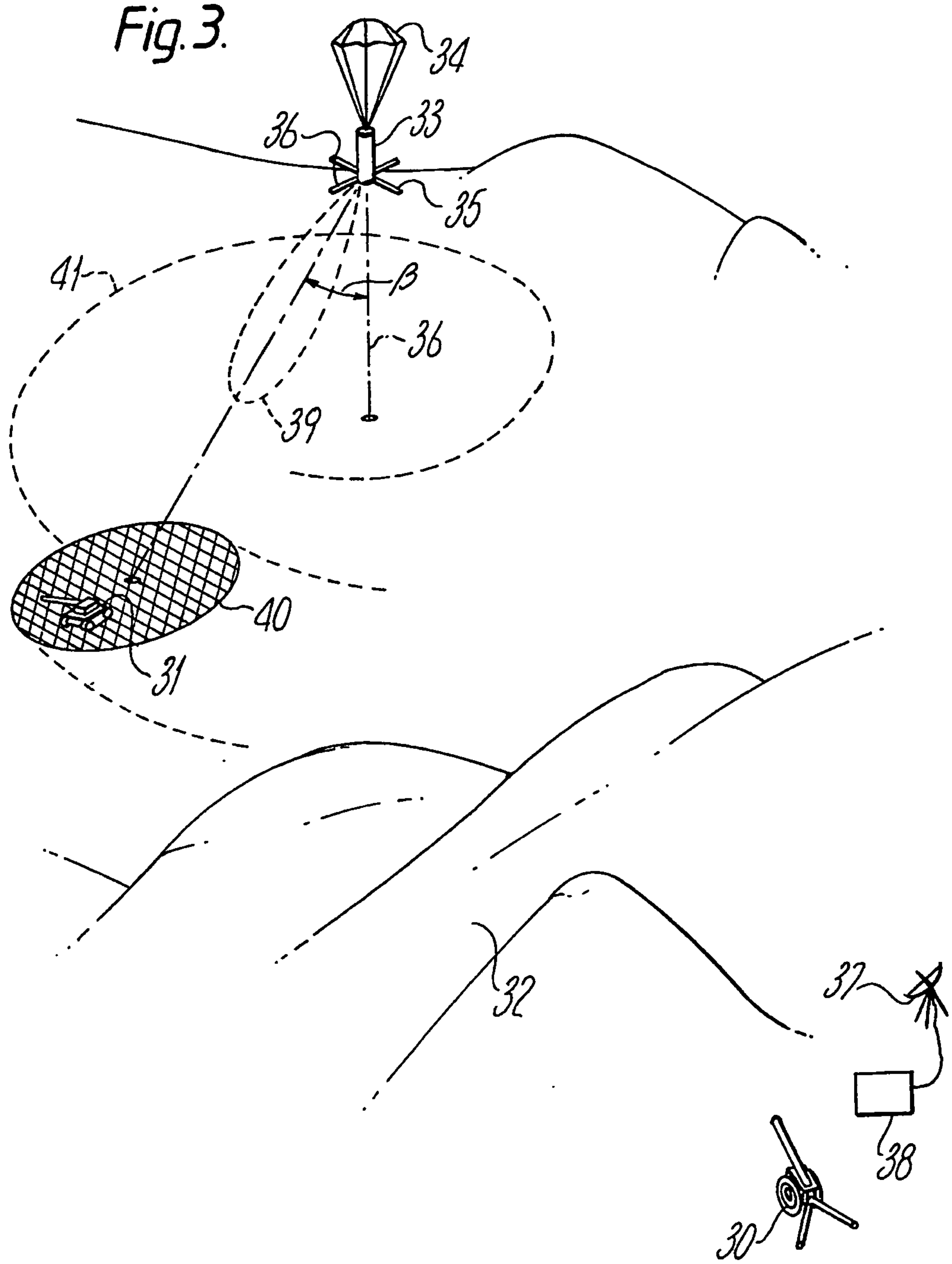


Fig.3.



SPECIFICATION

Directional acoustic receiving array

This invention relates to directional receiving arrays of transducers. Directional receiving arrays are known in respect of electromagnetic and acoustic elements for which the signals from the individual elements can be combined, by a process analogous to energisation of individual elements of a transmitting array to emit a directional beam, to form a reception beam whereby such receiving arrays are also known as beam forming arrays. This specification is concerned with acoustic transducers although the terminology and principles involved have corresponding realisations in electromagnetic aerial arrays.

Directional arrays of acoustic transducers have been widely used in sonar and other underwater operations where the sound sources of interest within the operating environment are such as to be readily defined in the design of a particular device.

Such underwater techniques are not readily applied to atmospheric sounds, where significantly greater attentuation particularly at higher frequencies, abundance of extraneous sources and wide spectral ranges of interest are encountered.

Early work in the field of atmospheric acoustic receiving arrays described by Billingsly, J and Kinns, R in J. Sound Vib. Vol. 48 (1976) P485, concentrated on beam forming when examining close objects of narrow spectral range and particularly the relationship between delays introduced into the different microphone circuits of the array in respect of the spherical wavefronts received from the source at short distances. In view of the focussing effect produced by the correct application of such delays the device was called an acoustic telescope and the name has been adopted by others for atmospheric acoustic beam forming receiving arrays.

One problem which is inherent to such acoustic telescopes is that for a particular beam direction the beam width that is, the main response lobe of the array varies inversely with frequency and a true telescope effect, that is, concentration upon a sharply delineated region with the elimination of sounds from sources surrounding this region has been possibly only at the expense of limitation to narrow frequency ranges.

It is an object of the present invention to provide an acoustic telescope able to define an atmospheric region of interest independently of source frequency and a reconnaissance system incorporating such an acoustic telescope.

According to a first aspect of the present invention an acoustic telescope comprises an array of spaced microphone transducers each transducer feeding signals into a microphone channel of process arrangement associated with the array, each microphone channel including a variable time delay means operable to delay the microphone signals by an amount determined by bean directing means, a plurality of filters, each defining a signal pass band channel different from others in the same microphone channel but corresponding to pass band channels in the other microphone channels, in which said microphone signals are band limited, pass band channel processing means arranged to receive band limited signals from each pass band channel of each microphone channel and responsive to selection of a desired reception beamwidth to apply the band limited signals with corresponding band limited signals of the other channels to band addition means, either directly, or by way of amplitude shading means operable to increase the beamwidth of the band limited signals, to the desired beamwidth, or, in addition with corresponding band channels of at least some of the other microphone channels, by way of pattern multiplication means operable to decrease the beamwidth of the band signal to the desired beam width, and output means operable to combine band limited signals from the addition means associated with each pass band channel so as to provide an indication of the detection of a source within any of the pass bands within a region defined by the desired beam width and the beam direction.

According to a second aspect of the present invention a reconnaissance system includes an acoustic telescope as defined in the preceding paragraph comprising a first part adapted to be launched by a projectile and ejected therefrom to fall to earth said first part containing an array of microphone transducers of the acoustic telescope and transmitter means operable to transmit signals produced by the transducers during descent to a second part, said second part containing a receiver of the transmitted signals and the microphone signal process arrangement of the acoustic telescope.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a schematic representation of a linear array of microphone transducers and a block diagram of signal process arrangement comprising a 1 dimensionally focussed acoustic telescope according to the present invention,

Figure 2 shows a series of response curves for the array of Figure 1 illustrating the variation received of beam width with source frequency, and

Figure 3 is a perspective view of a reconnaissance system illustrating 2-dimensionally focussed acoustic telescope according to the present invention comprising a pair of airborne orthogonally extending arrays observing a defined area of ground.

Referring to Figure 1 the acoustic telescope comprises a linear array 9 of omnidirectional microphone transducers 10 extending along an array line 11 each of which transducers producers signals representative of a source on microphone channels MC1 . . . MCn respectively of a process arrangement 12. Each microphone channel passes signals by way of a variable delay element 13 in which the signals can be delayed for a time interval determined by beam directing means 14. The beam directing

The drawing(s) originally filed were informal and the print here reproduced is taken from a later filed formal copy.

means 14 comprises a microprocessor programmed to produce a set of delays for the respective delay elements, to form a main response lobe of the array and thus a reception beam direction at a predetermined angle to the array direction 12. For a telescope focussed in the far field the wavefronts of signals emanating therefrom are assumed to be planar at the array and the delays are determined by trigonometrical calculation based upon the angle between the beam direction and the array line, the separation of the transducers and the velocity of the signals through the atmosphere (whether nominal or compensated with respect to prevailing atmospheric conditions).

Each microphone channel exiting from its delay element 13 is applied to the input of one of m pass band filters B1 ... Bm in which the microphone signals are split into band-limited components according to the pass bands of the filters. The pass bands of the filters are one octave wide and cover the audible spectrum. The output of each pass band filter is fed to a microphone channel matching means 15 arranged to compensate for variations in microphone or filter characteristics on said pass band channel B1 ... Bm. This matching is achieved during assembly of the telescope by placing a standard source at a fixed relationship to each microphone transducer in turn and adjusting the level of the band limited signals until the corresponding band limited signals of all the microphone channels are of the same value.

The signals on the band pass channels B1 ... Bm of each of the n microphone channels are fed band-by-band to pass band channel processing means PB1 ... PBm. Processing means PB1 has n inputs one for each microphone channel and switching means comprising a three-position switch 16 associated with each pass band channel. In a first position a first output of each switch is connected by a direct through line 17 to one input of band addition means 18 and in a second position a second switch output 19 connected by way of amplitude shading amplifier 20 to the line 17 (and thence to band addition means 18). Each amplitude shading amplifier 20 has a gain (which may be negative to effect attenuation) controllable by shading control means (not shown) in relation to the gains of the other (n-1) shading amplifiers whereby the band limited signals from the different microphone channels may be differentially amplified to affect the array response beamwidth for signals, within the associated pass band, output from the addition means 18.

Such amplitude shading is well known for signals derived from antenna arrays and will not be described in detail but its use in relation to the present invention will be referred to later.

In a third position a third output of each switch 16 is fed by way of a further switching means 21 to addition means 22. The combined signals of all the microphone channels that have closed switches 21 are fed to a pattern multiplication means 23. The pattern multiplication means 23 operates to multiply the signal from 28 by itself for a number of times determined by pattern control means (not shown). The output of the pattern multiplication means 23 is connected by line 24 to an input of the addition means 18.

Pattern multiplication is also a technique whose concepts are well known for signals derived from antenna arrays and the details of effecting it are not described here but its use in relation to the present invention will be referred to later.

The shading amplifier control means and pattern multiplication control means are not shown as physical structures and this control and control of the switching means 16 and further switching means 21 is effected by algorithms stored in the microprocessor 14 and based upon calculations relating to the desired beam width of the array.

The output of addition means 18 is fed by way of a variable gain adjustment device, an amplifier 25, to a mixer 26. The outputs of corresponding processing circuits PB2 .... PBm are also fed by way of variable gain amplifiers to different inputs of the mixer 26 which produces a composite signal for listening by an operator.

The principle of operation of the circuit of Figure 1 will now be described with reference also to Figure 2.

Graphs (a), (b), and (c) each illustrate the response of a linear array of microphone transducers having a particular number (n) of microphone transducers and spacings with the receiving beam directed normal to the line of the array to a source of single frequency.

Each graph shows the variation of intensity (relative to the maximum) in dB against the angular displacement from the normal in degrees. The graphs (a), (b) and (c) are for single frequency source of 4 KHz, 3KHz and 1KHz respectively and all show similar characteristics of a main lobe and a series of side lobes of decreasing intensity (not all of which are shown).

In respect of delineating a region of detection, analogous to a definite field of view of an optical telescope, the main considerations are of the beam width, measured by the width of the main lobe at the -3dB point, and the relative amplitude of the side lobes.

One form of signal manipulation used in respect of antenna arrays is amplitude shading whereby signals from the elements towards the ends of the array are attenuated relative to signals from the element towards the centre. There are several methods involving different ratios, such as the binomial method and Dolph-Chebychev method. Superimposed upon the graph (a) in chain dotted lines is the response to the same signal when shaded by the Dolph-Chebychev method, the result being a widening of the main beam lobe from 6° to 9° at the -3 dB point and a 40 dB rejection of the first side lobe. Such amplitude shading is applicable where it is desired to reject side lobes and/or increase the main beam width of the main lobe.

Another form of signal manipulation used in respect of signals from antenna arrays is pattern multiplication where signals from sources having different responses are multiplied to emulate an array of a larger number of reception elements with a correspondingly narrower beam width. Such pro-

cedure may be applied to signals from a single array which are multiplied together, or squared, the effect being to reduce the width of the main lobe, by so-called self multiplication. Alternatively pattern multiplication may be carried out in accordance with a time-average-product (T.A.P.) beam forming process, as discussed by Berman, A and Clay, C. S. in an article entitled "Theory of Time Averaged Product Arrays" in the Journal of the Acoustical Society of America Vol. 29 (1957) P. 805. While reducing the main lobe width the technique of pattern multiplication has no effect on the signal-to-noise ratio of the signal (that is, the side lobes are similarly reduced in width but do not diminish in amplitude relative to the main lobe).

It will be seen from the responses illustrated in (a) (b) and (c), that the 'natural', or 'unshaded' main lobe width (measured at the –3 dB level) increases with decreasing frequency.

It will be appreciated that for a source emitting several different frequencies an array signal will have a beam width which varies with frequency and which does not naturally produce a sharply defined field of view in a region surrounding the steered beam direction.

In one manner of operating the acoustic telescope of Figure 1, a beam width is defined to delineate the field of view required (and which for sources in the far field is virtually independent of distance). Suppose a beam width of 9° is chosen, then for an array having the characteristics in respect of number of transducers and spacings thereof used to produce the graphs of Figure 2 it will be seen that the frequency having this beam width naturally is 3KHz (graph b). At frequencies above this the beam width is narrower than required and at frequencies below this the beam width is wider. The pass bands B1 – Bn are fixed for the telescope, for example, as one octave ranges, so that the signals in some of the bands will be below the natural frequency, signals in one band will include the natural frequency and the signals in the remaining bands will be in excess of the natural frequency.

In the processing means associated with the band including the natural frequency all switches of the switching means 16 are set to their first positions so that the signals pass through to addition means 18 unmodified. The processing means associated with each of the bands of higher frequency have their switching means set to the second switch output 19 so that the signals from the microphone channels associated with that passband are passed to the addition means 18 by way of the shading means 20 which is organised to increase the 3dB beamwidth to that of the natural frequency, for example, from 6° to 9° at 4KHz which also beneficially reduces the side lobes.

In each processing means associated with each of the bands of lower frequency the switching means is set to the third position so that the signals from the microphone channels associated with that pass band are passed by way of addition means 28 and pattern multiplier means 23 where the beamwidth of the main lobe is reduced to that of the natural frequency, for example from 24° to 9° at 1KHz, and thence to the addition means 18. As stated above the number of multiplications required for low frequency signals may result in a poor signal-to-noise ratio. One technique of reducing the number of multiplications required is to reduce the beam width partially by increasing the spacing between the transducers. This may be done without physical disturbance of the array by switching out some of the microphone channels at the pass band by means of further switches 21, although a reduced signal level results.

Whichever path taken by the band limited signals through the respective processing means the signals appearing at the outputs of each band addition means are from within the natural beamwidth selected as the field of view of the telescope and independent of source frequency. The signals after passing through amplifiers 25, are mixed by mixer 26 and monitored aurally by an operator. The gain of each amplifier 25 is adjustable by the operator so that any signals in any hand of particular interest can be enhanced, or depressed.

It will be appreciated that the control of switching means 16 and the individual shading and multiplication responses depend upon the beamwidth desired and on the natural frequency which provides such a beamwidth. The microprocessor 14 is programmed for the particular array configuration to relate the natural frequency corresponding to any demanded beamwidth and is programmed to control the switching means 16, the shading ratios and pattern multiplication (including further switching means 21) to achieve this.

If desired the control means associated with defining the operation of each processing means may be provided by discrete individually operable units preset or controlled by the listening operator in accordance with a set of tables listing the processing means parameters for a desired beamwidth.

Similarly the beam directing means 14 controlling the delay element 13 may be a hardwired circuit instead of a microprocessor to provide different delays for different microphone channels required to direct a reception beam in different directions. A microprocessor is particularly useful in rapidly calculating the relative delays required for small frequency changes in beam direction and enabling the beam to be scanned automatically or steered to any position under the influence of the listening operator or for detection of a source to lock onto and follow the source.

It will be appreciated that by suitable programming of the beam directing means 14 delays consistent with the arrival of spherical wavefronts may be applied to the delay elements 13 whereby the array has a field of view focussed at a predetermined distance from the array rather than at infinity.

The telescope described above represents a general purpose arrangement in which each band processing means is capable of providing a full range of shading or pattern multiplication functions and it will be appreciated that constructional variations may be made to suit any particular application.

For instance, the array form may be chosen as regards the number, spacing and regularity of spac-

ing of microphone elements to produce desired operating characteristics. The pass band filters which in the described embodiment have a one octave wide pass band may have pass bands of any desirable width, the desirable features of the filters being a relatively uniform response to frequencies within each pass band and a band-edge roll-off which does not overlap, nor leave a gap between, the adjacent band. If the operational variations in beamwidth are expected to be small then only a relatively small number of processing means associated with the pass bands of the natural frequencies related those beamwidths require facilities for switching between a shading and pattern multiplication activity. Pass band channel processing means associated with frequencies above this may have only shading function and those associated with lower frequencies may have only a pattern multiplication function.

Also instead of, or in addition to, the audible output provided by the mixer 26 the outputs of the band addition means may be fed to optical indication means such as separate indicator lamps or in combination to one single indicator lamp or to cause picture enhancement on a video display. The latter arrangement is particularly useful when the field of view of the acoustic telescope is coincident with that of optical imaging means which produces a video output, as a means of 'reinforcing' detection of a source which may not be readily discernable from the optically generated image alone.

The acoustic telescope according to the present invention is thus able to provide real-time acoustic monitoring of a limited field defined by the direction of the reception beam of the array.

It will be appreciated that the microphone transducers of the array are individually receiving signals from all sources in all directions so that a single array is capable of feeding the microphone channels of different processing arrangements of the type shown in Figure 1 whereby a plurality of reception beams may be formed and monitored by different operators or provide visual indicators to which an operator can select an audible output.

Unless multiple-beam real time operation is required continuously the microphone transducer signals from each microphone channel may be recorded by a multichannel tape recorder 27 as shown in Figure 1. The signals may be monitored in real time for a preferential beam direction or scan and then replayed when the array is no longer functioning to search for additional sources in different beam directions or scan patterns.

For ease of understanding the above description has related to a single linear array of transducers which is able to produce a detection field limited in the direction of the array line 12 only. To define a two dimensionally bound region a pair of linear arrays may be inclined to each other, such as at right angles. A detection field, or beam, is defined in respect of its direction by directing the field of view of each beam such that it intersects that of the other in the required direction from the joint array, and in respect of its boundaries by selecting the beam width to be processed for each array in a separate process arrangement. The outputs of corresponding band addition means of each process arrangement feeds the beam formed band limited signals thereof to further pattern multiplication means (not shown but similar to 23) so as to reinforce signals from the intersecting parts of the beams while suppressing signals from other parts of the fields of view of the individual arrays. The reinforced product signals are then passed by way of the variable gain amplifiers 25 to the mixer 26 for direct listening or combined in some other way for visual indication as described previously.

Clearly in such a two-dimensionally limiting device the directing of the composite detection beam is a function of the beam direction of each array and a single beam directing means 14 such as provided by the microprocessor can be set to calculate and apply the delays to the delay means 13 of the microphone channels of both arrays. In particular microprocessor control permits the two-dimensionally limited beam to scan though a region of interest in any pattern and/or track a source as a result of detection. Other variations described above for the single array telescope are applicable also to a multiple array device.

It will be understood by those skilled in the art that while a pair of inclined arrays defines a two dimensionally bounded reception beam there will be ambiguity of direction with respect to the plane of the arrays. This may be avoided by the use of a third array of microphone transducers inclined out of plane of the others or by mechanical shading of the transducers of the arrays from reception from an undesirable direction.

The array configurations described above are also open to variation in a manner known for antenna arrays where the properties of such arrays are suitable. For example, a circular array of microphone transducers produces an oppositely opposed pair of main beam lobes along an axis extending out of the plane of the array and through its centre.

A practical example of an acoustic telescope embodying the general principles described above is a reconnaissance system illustrated in Figure 3. An artillery emplacement 30 hidden from an enemy 31 by a range of hills 32 launches a first part of the reconnaissance system, an observation device, by means of an artillery shell or like projectile, such that the device is ejected from the projectile and falls to earth slowly, retarded by parachute 34. The observation device 33 carries a pair of orthogonal arrays 35, 36 of microphone transducers forming part of an acoustic telescope which are deployed for the descent, and orientation and altitude measuring device and a multichannel radio frequency transmitter for the microphone, altitude and orientation signals (not shown). The observation device is constructed to fall substantially vertically along an axis of descent 36 without rotation about the axis.

A second part of the reconnaissance system is located on the ground near the artillery emplacement and includes 37 arranged to received signals transmitted by the observation device which are passed to a ground station 38. The ground station 38 comprises a multichannel receiver and for each

array a process arrangement as shown in Figure 1, with the difference that the microphone channels MC1-MCn are coupled by way of the transmitter and receiver rather than directly.

The beam directing means which operates only upon the received signals causes a beam to be formed (as represented by lobe 39) which defines a region 40 where it intersects the earth and which is caused to scan in a circular sweep around the axis of descent at a constant angle β. It will be appreciated from Figure 4 that as the observation device descends the Locus 41 of the region 40 traces out an inwardly moving spiral so that the whole region is scanned for sources of audible sounds.

Knowing the orientation of the observation device and thus of the arrays it is possible to relate the detection of a source at any time with the altitude to designate the area 40 in 'view' at that time, on maps used by the artillery emplacement.

Such detection means serve as the basis for directing a projectile from the gun 30.

There are several modifications possible to this basic system which will be apparent from the above description. The processing arrangement of ground station 38 may be arranged such that upon detection of a target, such as 31 within a region 40, the beam width is narrowed and scanned within the region 40 until the target is again detected and the more accurately defined position for the target given. The beam may then revert to the 'wide' beam scanning or may be locked onto the target.

The observation device may also carry optical camera means (not shown) which is caused also to scan the area as the device 33 descends and transmit pictures thereof to the ground station. If the field of view of the camera is arranged to coincide with that 40 the acoustic telescope may help in positive identification of a target which is not readily discernable optically, for instance if hidden by smoke, dust or foliage.

The ground station 35 preferably includes a multichannel tape recorder (as shown at 27 in Figure 1). As the observation device is able to make one descent only it is possible to make real-time acoustic observations for a limited time only. By recording the signals it is possible to 'replay' the descent at the ground station steering the reception beam 39 on different paths to cover different areas of ground.

In this way several targets may be identified. However it must be remembered that such observations are of the situation in the past and targets may have moved to a different position. However such additional off-line scanning and perhaps even such scanning repeated with a beam covering a much wider area providing an overview of the enemy territory may serve to direct further observation devices to a region of known enemy activity rather than at random.

It will be seen that such an acoustic telescope, particularly in combination with an optical camera, is able to provide information not only during the limited time of descent but also after the descent and over different regions of interest. Furthermore the acoustic telescope is in two parts, relatively inexpensive expendible arrays of microphone transducers are carried by the observation device while means for enabling beam scanning and changes to the field of view are all located at the protected ground station.

The reconnaissance device described contains two linear arrays to define a 2-dimensionally limited beam. It will be appreciated that other array configurations, such as a circular array may be used to provided such a beam. Other beam patterns may be desirable, such as obtained from a single linear array which will form a beam intersecting a strip of land, such a strip being scanned transversely to its length.

CLAIMS

1. An acoustic telescope comprising an array of spaced microphone transducers each transducer feeding signals into a microphone channel of process arrangement associated with the array, each microphone channel including a variable time delay means operable to delay the microphone signals by an amount determined by beam directing means, a plurality of filters, each defining a signal pass band channel different from others in the same microphone channel but corresponding to pass band channels in the other microphone channels, in which said microphone signals are band limited, pass band channel processing means arranged to receive band limited signals from each pass band channel of each microphone channel and responsive to selection of a desired reception beam width to apply the band limited signals with corresponding band limited signals of the other channels to band addition means, either directly, or by way of amplitude shading means operable to increase the beamwidth of the band limited signal, to the desired beamwidth, in addition with corresponding band channels of at least some of the other microphone channels, by way of pattern multiplication means operable to decrease the beamwidth of the band signal, to the desired beam width and output means operable to combine band limited signals from the addition means associated with each pass band channel so as to provide an indication of the detection of a source within any of the pass bands within a region defined by the desired beam width and the beam direction.

2. An acoustic telescope as claimed in claim 1 in which pass band is one octave wide within the spectral region of interest.

3. An acoustic telescope as claimed in claim 1 or claim 2 in which the spectral region of interest is within the human audible range.

4. An acoustic telescope as claimed in any one of claims 1 to 3 including microphone transducer matching means operable to match the signals of each microphone channel for identical sources.

5. An acoustic telescope as claimed in claim 4 in which the matching means is operable to perform said matching for each pass band channel of each microphone.

6. An acoustic telescope as claimed in any one of claims 1 to 5 in which at least some of the pass band processing means include switching means settable to pass the band limited signal either directly to the band addition means, to the amplitude shading means the pattern multiplication means.

7. An acoustic telescope as claimed in claim 6

including switching control means operable to set the switching means as a function of the pass band in which the natural beam width of the main lobe of the array corresponds to the desired beam width, signals in bands of higher frequencies being passed to the amplitude shading means and signals in bands of lower frequencies being passed to the pattern multiplication means.

8. An acoustic telescope as claimed in any one of claims 1 to 7 in which the amplitude shading means comprises amplification means associated with each microphone channel of each pass band and amplitude shading control means operable to control the relative gains of the amplification means in accordance with a calculated shading function.

9. An acoustic telescope as claimed in claim 7 in which the amplitude shading control means is operable to derive the shading function in accordance with the Dolph-Chebychev method.

10. An acoustic telescope as claimed in any one of claims 1 to 9 in which each pattern multiplication means comprise a self multiplication means comprising an analogue (mathematical) squaring circuit in which the summed band limited signals of the pass bands associated therewith are multiplied by themselves for a set number of times determined by pattern multiplication control means.

11. An acoustic telescope as claimed in claim 10 in which the pattern multiplication control means is operable to set the number of multiplications in accordance with the reduction of beam width sought.

12. An acoustic telescope as claimed in claim 10 or claim 11 in which the pattern multiplication means includes further switching means responsive to further switching control means to apply the band limited signals only from selected channels to the multiplication means effectively increasing the spacing between microphone transducers and reducing the natural beam width in that frequency band, prior to multiplication.

13. An acoustic telescope as claimed in any one of the preceding claims in which the output means includes an audio mixer for the output of each band addition means operable to provide an audio frequency output extending over the spectral range of the pass bands for direct audible monitoring by an operator.

14. An acoustic telescope as claimed in any one of the preceding claims in which each pass band channel includes a variable gain adjustment device prior to the mixer operable under the control of an operator to accentuate or depress the beam response in any particular pass band or bands.

15. An acoustic telescope as claimed in any one of the preceding claims in which the beam directing means comprises a microprocessor programmed to determine the durations of delays required to be applied to the signals of individual microphone transducers to form a beam directed in any selected direction with respect to the array.

16. An acoustic telescope as claimed in claim 15 when dependent from claim 7 in which the microprocessor is also programmed to function as the switching control means.

17. An acoustic telescope as claimed in claim 15 when dependent from claim 9 in which the microprocessor is also programmed to function as the amplitude shading control means.

18. An acoustic telescope as claimed in claim 15 when dependent from claim 11 in which the microprocessor is also programmed to function as the pattern multiplication control means.

19. An acoustic telescope as claimed in claim 15 when dependent from claim 12 in which the microprocessor is also programmed to function as the further switching control means.

20. An acoustic telescope as claimed in any one of the preceding claims in which the microphone transducers are onmidirectional.

21. An acoustic telescope as claimed in claim 20 including mechanical shading means for the array operable to prevent microphone pick up of sounds from undesirable directions.

22. An acoustic telescope as claimed in any one of claims 1 to 19 in which the array is a circular array.

23. An acoustic telescope as claimed in any one of the preceding claims in which the array is a linear array.

24. An acoustic telescope as claimed in claim 23 including a second array of spaced microphone transducers inclined to the first and a second process arrangement associated therewith and including combination means operable to multiply the pass band limited signals from corresponding pass band channels of each process arrangement before application of said signals to the output means.

25. An acoustic telescope as claimed in claim 24 in which the beam directing means of one processing arrangement coordinates the delays for both processing arrangements.

26. An acoustic telescope as claimed in any one of the preceding claims including recording means operable to record the microphone signals from each microphone channel before they are applied to the beam directing means and operable to reproduce said signals and apply them to the beam directing means at a later time.

27. An acoustic telescope substantially as herein described with reference to, and as shown in, the accompanying drawings.

28. A reconnaissance system including an acoustic telescope as claimed in any one of the preceding claims comprising a first part adapted to be launched by a projectile and ejected therefrom to fall to earth, said first part containing an array of microphone transducers of the acoustic telescope and transmitter means operable to transmit signals produced by the transducers during descent to a second part, said second part containing a receiver of the transmitted signals and the microphone signal processing arrangement of the acoustic telescope.

29. A reconnaissance system as claimed in claim 28 in which the first part includes means operable to determine array orientation and provide a signal for transmission to the second part and in which the second part includes means responsive to an indication of the array orientation from the first part and to detection of a source at a particular orientation with respect to the array as determined by the acoustic

telescope to relate the detection of a source to a region of the territory being reconnoitred.

30. A reconnaisance system as claimed in claim 28 or claim 29 including means operable to determine the heght of the first part above the landing point and provide a signal for transmission to the second part and in which the second part includes means responsive to an indication of the height of the first part to relate the detection of a source to a region of the territory being reconnoitred.

31. A reconnaisance system as claimed in any one of claims 28 to 30 in which the first part includes optical camera means operable to observe different areas of ground during the descent and means to transmit signals representing the camera image to the second part, said second part including means operable to display said camera images of the ground and control the process arrangement of the acoustic telescope to define a region of acoustic detection coincident with that of the camera image.

32. A reconnaissance system as claimed in claim 31 in which the output means of the acoustic telescope is arranged to vary the intensity of the displayed camera image in response to detection of a sound source from the region covered by the image.

33. A reconnaissance system substantially as herein described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1982.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.